GPS ASSISTANCE MESSAGES IN CELLULAR COMMUNICATIONS NETWORKS AND METHODS THEREFOR

FIELD OF THE INVENTIONS

The present inventions relate generally to locating mobile stations in cellular communications networks, more particularly to mobile station Global Positioning System (GPS) assistance messages transmitted to cellular handsets and methods therefor.

BACKGROUND OF THE INVENTIONS

In Assisted GPS mobile station positioning schemes, one or more ground based referenced station nodes coupled to a cellular communication network receive GPS satellites data and re-transmit the data in the form of assistance messages at higher data rate over the cellular air interface to mobile stations for use in position determination.

There are several types of GPS assistance messages. Ephemeris assistance messages include GPS ephemeris and clock correction data. Almanac assistance messages include almanac and other data, which includes generally truncated ephemeris, ionospheric delay elements, universal time coordinate (UTS) offset, and other data. Differential GPS (DGPS) assistance messages include differential correction data.

In some cellular communications architectures, for example the 3rd generation (W-CDMA/UMTS) architecture, one or more a value tags are included in a header, or Master Information Block (MIB) transmitted separately from the assistance message by the network. In the W-CDMA/UMTS architecture, the

assistance message is referred to as a System Information Block (SIB). The MIB and SIB are generally transmitted according to different schedules.

The value tags of the MIB generally provide scheduling information and inform the cellular mobile stations whether the content of the corresponding assistance message has been updated. Currently, a multi-bit cell value tag is used for Global Positioning System (GPS) assistance messages in the W-CDMA/UMTS specification. The GPS value tag is updated whenever any data, for example the GPS time stamp ("Transmission TOW" in the W-CDMA/UMTS specification), of the assistance message (SIB in W-CDMA/UMTS) is updated or changed.

Each assistance message, or SIB, is valid generally for a specific geographic area, for example for a particular cell or for a particular Public Mobile Land Network (PLMN). When a new MIB is read by the mobile station, its value tag for the corresponding SIB in the local cell or PLMN is compared to the value tag of the corresponding SIB stored previously in the mobile station. Presently, the mobile station ("User Equipment" in the W-CDMA/UMTS specification) updates the SIB any time the value tag of the corresponding MIB has been updated. Reading the SIB however consumes substantial power, which is a limited resource in battery powered mobile stations.

BRIEF DESCRIPTION OF THE DRAWINGS

The various aspects, features and advantages of the present invention will become more fully apparent to those having ordinary skill in the art upon careful consideration of the following Detailed Description of the Inventions with the accompanying drawings described below.

FIG. 1 illustrates a cellular communications network supporting assisted GPS location of a satellite positioning system enabled mobile receiver.

FIG. 2 illustrates an ephemeris data update process flow diagram.

FIG. 3 illustrates periodic GPS ephemeris data transmission from GPS satellites.

FIG. 4 illustrates a binary sequence having a satellite identifier and a corresponding ephemeris data identifier.

FIG. 5 is illustrates a sequence of binary bits.

FIG. 6 illustrates an almanac data update process flow diagram.

DETAILED DESCRIPTION OF THE INVENTIONS

FIG. 1 is a network-assisted satellite positioning system 100 including generally a reference receiver 110 at a surveyed location having an unobstructed skyward view of satellites 120 in a constellation, and a server, or reference node, 130 coupled thereto. In some networks, the reference receiver is a part of the server or vice versa and the combination thereof constitutes the reference node. In other networks, the server is at another location. The reference node is generally coupled to several network base stations directly or indirectly via other network nodes, only one of which, base station 140, is identified.

The reference receiver receives satellite signals, and the reference node generates GPS assistance messages based on the received satellite signals in a format suitable for transmission over the network to one or more mobile receivers. The assistance messages are generally modulated on a cellular carrier signal 101,

which is transmitted in a point-to-point mode to a particular cellular handset 104, or in a point-to-multipoint, or broadcast, mode to multiple mobile receivers.

The reference node also generates GPS data issue identifiers for transmission to GPS enabled mobile stations in cellular communications networks. The GPS data issue identifiers are used to indicate whether GPS data, for example corresponding ephemeris and almanac data stored at the mobile station requires updating.

FIG. 2 illustrates a process flow diagram 200 for updating a GPS ephemeris data issue identifier transmitted to a GPS enabled mobile station in a cellular communications network. Generally, a reference node, illustrated in FIG. 1, receives ephemeris data from each of a plurality of GPS satellites (usually 8-12 satellites) at block 202. Reference herein to "ephemeris data" includes generally ephemeris and correction clock data received at the reference node from a corresponding GPS satellite.

An ephemeris assistance message is generated including ephemeris data, correction clock data and other parameters, some of which may be provided by the network, for each satellite at block 204.

The ephemeris data including the correction clock data and the other parameters are updated at some known transmission interval, approximately 1 hours as discussed more fully below, also at block 202. Other data and parameters, for example transmission time as shown later as the first parameter of Tables 2 and 3, may be updated more frequently. The corresponding ephemeris assistance messages are also updated at block 204 based on the updated ephemeris data, correction clock data and other data and parameters communicated by the network in the assistance message.

than the update frequency of the ephemeris data. The age of the ephemeris data may determined in the handset by calculating: $t - t_{oe}$, where "t" is the current time and "t_{oe}" is the Time of Ephemeris.

FIG. 3 illustrates an exemplary GPS almanac assistance message comprising the parameters shown in Table 2.

Table 2 illustrates an exemplary GPS almanac assistance message comprising the parameters shown in Table 2.

Table 2: Exemplary Content of the Almanac and Other Data Assistance Message

<table>
<tr><th>Parameter</th><th>Description</th><th>Units</th></tr>
<tr><td>Transmission TOW</td><td>Approximate GPS time of week when this message is transmitted</td><td>Secs</td></tr>
<tr><td>SV Mask</td><td>Indicate the SVs that contain the pages being transmitted in this message</td><td></td></tr>
<tr><td>LSB TOW</td><td>Least significant 8 bits of time of week</td><td>Secs</td></tr>
<tr><td>SFID 0</td><td>Least significant bit of subframe (SF) ID</td><td rowspan="9">Repeat three times each corresponds to a different page no. as described in Table 3</td></tr>
<tr><td>Data ID</td><td>Indicate the data ID field</td></tr>
<tr><td>Page No.</td><td>Page No. of the SF for the following words</td></tr>
<tr><td>Word 3</td><td></td></tr>
<tr><td>Word 4</td><td></td></tr>
<tr><td>Word 5</td><td></td></tr>
<tr><td>Word 6</td><td></td></tr>
<tr><td>Word 7</td><td></td></tr>
<tr><td>Word 8</td><td></td></tr>
</table>

Word 9		
Word 10		

Similarly, there is one parameter in the almanac data that indicates age of the current almanac data issue, i.e., time of almanac (t_{oa}) applicability. As a result, t-t_{oa} age limit can be used by the handset to determine when it is necessary to read the cellular network transmitted almanac data again. The almanac assistance messages transmitted by the network may thus be ignored until the stored almanac set reaches its age limit, for example where the broadcast frequency of the almanac assistance message is greater than the update frequency of the almanac data. The age of the almanac data may be determined in the handset by calculating: $t - t_{oa}$, where "t" is the current time and "t_{oa}" is the Time of Almanac.

Table 3: Mapping of Almanac and Other Data to Subframe ID and Page Numbers

Data Type	Subframe	Page(s)
Almanac Data (SV1-24)	5	1-24
Almanac Data (SV25-32)	4	2-5,7,8
SV Health (SV1-24)	5	25
SV Health (SV25-32)	4	25
Ionospheric/UTC	4	18

Listed below is an exemplary DGPS correction assistance message comprising the parameters shown in Table 4.

Table 4: Exemplary Content of the DGPS Assistance Message

Parameter	Description	Parameters Sent
GPS TOW	GPS time of week at which the correction data is valid, secs	Once per message
Status/Health	Health and Status, including UDRE SF	Once per message
N_SV	Number of satellites for which corrections appear	Once per message
SVID	GPS satellite for which corrections apply	N_SV times
IODE	Current ephemeris issue for which the corrections apply	N_SV times
UDRE	User Differential Range Error (accuracy predictor, meters)	N_SV times
PRC (or PRC - PRC_{avg})	Compressed pseudo range correction, meters	N_SV times
RRC (or RRC – RRC_{avg})	Compressed range rate correction, meters/sec	N_SV times

ΔPRC_i	Difference in PRC values, meters	i times
ΔRRCi	Difference in RRC values, meters/sec	i times

This message contains several aspects of the intelligent compression. They are evident from Table 4, while others are more subtle. The DGPS time tag (GPS TOW) is compressed relative to the full twenty bits of the RTCM standard for DGPS correction data due to each mobile having reasonably reliable timing information. The differential correction data itself is compressed either by simply reducing the bits defined in RTCM while maintaining the required location accuracy or by subtracting the average value of the corrections across all satellites from each PRC and RRC value. This average value reflects the common time and frequency biases in the correction data which are induced by the oscillator offset and drift. These biases have no effect on the navigation solution of the differentially corrected mobile stations and so can be removed. Alternatively, if the DGPS reference receiver has already removed the average of the correction values, or the drift of the DGPS reference receiver's clock is known to be insignificant relative to the correction values, then this operation is not required. In addition, it is usually not necessary to include ΔRRC values for the previous IODE's, since the velocity errors induced by ephemeris age are small relative to the nominal latency errors. However, in certain applications, where velocity accuracy is important, it can be advantageous to include them. In addition, when SA is de-activated by the Department of Defense, the errors induced by neglect of the ΔRRC values will become more significant, relatively speaking. Therefore, ΔRRC could be optional. Depending on the particular application, certain parameters can be optional too or

additional parameters can be included. The parameter i in Table 4 indicates the number of previous IODE values which are included: this number will range from 1-4, depending upon the bandwidth reduction required (a value of 4 corresponds to the maximum infrastructure bandwidth reduction). Additionally, if fewer than 4 is utilized for this parameter, the ΔPRC (and perhaps ΔRRC) values need not be continuous: i.e., it may be advantageous to skip the ΔPRC (and perhaps ΔRRC) values for the ephemeris copy closest to the current ephemeris, since it produces the smallest differences. For example, one can transmit the corrections of the current IODE with the one prior to the one older than the current IODE. Finally, because the ΔPRC difference values are driven by ephemeris age error and not by normal DGPS latency effects (e.g., SA acceleration), they do not have to be sent as frequently as every short period, such as thirty seconds. A longer broadcast period will aid in data compression. In the worst case, sending the ΔPRC difference values once a longer period, such as per minute, or even longer when SA is off, will suffice. One option is to use a Δ_Count parameter to indicate this alternating scheme. The worst case occurs when the ephemeris is oldest, which suggests an additional compression of the data based inversely on age: i.e., the more recent PRC difference values will be sent less frequently. Using these two compression techniques, the number of bytes needed to transport the DGPS message to all visible satellites is less than eighty-two bytes. Of course, if the message length is less a concern, the compression techniques described above become optional. Despite this obvious fact, the principle of applying DGPS corrections based on the current and previous IODEs is still valid for transmission bandwidth savings, i.e., by reducing or eliminating the frequent update of the ephemeris and clock correction data.

While the present inventions and what is considered presently to be the best modes thereof have been described in a manner that establishes possession thereof by the inventors and that enables those of ordinary skill in the art to make and use the inventions, it will be understood and appreciated that there are many equivalents to the exemplary embodiments disclosed herein and that myriad modifications and variations may be made thereto without departing from the scope and spirit of the inventions, which are to be limited not by the exemplary embodiments but by the appended claims.

What is claimed is: